



October 26, 2016

Attention: Document Control Desk
Director, Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

40-7580

SMB-911

Re: September 2, 2016 NRC provided to FMRI Inc. request for Additional Information (RAI)

Director:

By letter 02 September 2016, NRC provided to FMRI, Inc. (FMRI) request for additional information (RAI) regarding the 10 June 2016 submittal for derived concentration guideline levels (DCGLs). The RAI included two items: RAI-1 and RAI-2. Response to each is provided as follows:

RAI-1

NRC Comment: Revised DGCLs for Elevated Measurement Comparisons (DCGL_{EMC}) are needed for soils and sediments incorporating changes made to the FMRI RESRAD model since the 2003 Decommissioning Plan (DP) was drafted, including any changes made in response to RAI-2. FMRI should either provide revised DCGL_{EMC}'s or provide adequate justification as to why this is not needed.

FMRI Response: The Forbearance Agreement of August 17, 2015 at conditions 5.A. and 5.B. distinguishes between revision of DCGLs and development of a Final Status Survey Plan. The MARSSIM makes an equivalent distinction by stating the development of DCGLs is outside its' scope but provides specific guidance for development and application of the DCGL_{EMC} for a final status survey. The DCGL_{EMC} values are a modification of the DCGLs and thus cannot be determined until the DCGLs are established. FMRI recognizes revision of DCGL_{EMC} values as a matter of the final status survey. FMRI will provide DCGL_{EMC} values within the Final Status Survey Plan.

RAI-2

NRC Comment: To meet the 10 CFR 20.1402 regulatory requirement, additional revisions to the FMRI RESRAD model are needed to adequately consider the groundwater pathway. Additional

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sensitivity analyses should include sorption coefficients (K_d values) for the contaminated, unsaturated and saturated zones as well as the thicknesses of the contaminated and unsaturated zones and the well pump intake depth (screened thickness of the saturated zone). The range for the thickness of the unsaturated zone should account for excavated areas and variations in the depth of contamination. Either conservative or site-specific values should be used for parameters to which the dose is sensitive, in accord with the NRC Consolidated Decommissioning Guidance (NUREG-1757, Volume 2, Revision 1, Appendix I). FMRI should provide the noted revisions or provide adequate justification as to why the revisions are not needed.

FMRI Response: FMRI completed the additional sensitivity analyses noted in the NRC Comment. Enclosure provides the results of the revised sensitivity analyses of the June 2016 DCGLs. Enclosure also identifies each RESRAD parameter, provides the FMRI input (value), including revision of distribution coefficient in response to sensitivity analyses, and provides a basis for the value. Enclosure finally provides DCGLs revised pursuant to response to the subject RAI.

Sincerely,

A handwritten signature in black ink, appearing to read "Robert Compennolle".

Robert Compennolle
FMRI, Inc.
Number 10 Tantalum Place
Muskogee, OK 74403

CC: Gregory Chapman NRC/NMSS/DUWP/MDB
Pam Dizikes, Oklahoma Department of Environmental Quality
Richard Gladstein, Department of Justice
Christina England, Office of General Council NRC

FMRI, Inc.

Docket No. 40-7580

October 2016

**REVISION OF DERIVED CONCENTRATION GUIDELINE LEVELS
Industrial Worker Scenario**

ATTACHMENTS

Attachment 1

**RESRAD SUMMARY REPORT
Industrial Worker Scenario**

Attachment 2

**SENSITIVITY ANALYSIS
Industrial Worker Scenario**

REVISION OF DERIVED CONCENTRATION GUIDELINE LEVELS

Introduction

Fansteel submitted a decommissioning plan (DP) to NRC in 2003.¹ The DP at Section 5.0 Dose Modeling Evaluations developed radiological criteria for license termination as concentrations of radionuclides in soil and on building and component surfaces; i.e., derived concentration guideline levels (DCGL). Development of the DCGLs for soil presumed that exposure of the critical group via drinking water from on site groundwater was not an applicable exposure pathway.

FMRI did not provide an adequate defense for excluding the exposure pathway of drinking water from on site groundwater.² Additionally, a technical concern was identified that some parameter values were established to be conservative (i.e., expected to result in a higher projected dose than if using the true value of the parameter) for a scenario in which the drinking water pathway was excluded but do not appear to be appropriate for a scenario in which a drinking water pathway is included.²

FMRI provided response to the aforementioned technical concern by revision of DCGLs for soils.³ FMRI reviewed the values of inputs to the dose model as described in the DP with intent to revise any values that were not appropriate. During the review, FMRI recognized that the original value for some parameters were not readily reproducible or were not internally consistent; thus model values were also revised in this context.

NRC staff reviewed the revised DCGLs and identified two requests for additional information (RAI).⁴ The second RAI (RAI-2) involved expanding the scope of sensitivity analyses and possibly revising values of some parameters as a result.

Scope of Revision

The response to RAI-2 includes revision, again, of the values for several soil parameters with intent of providing internal continuity and better representation of site conditions. The transport distribution coefficient for uranium was revised as a result of the sensitivity analyses.

The following sections identify which dose model inputs were revised and the revised value, and which model inputs were not changed.

¹ Fansteel. Decommissioning Plan, Fansteel, Muskogee, Oklahoma Site. Rev. 0. January 14, 2003. [ML030240051]

² Michael A. Norato, U.S. Nuclear Regulatory Commission, to Robert Compennolle, FMRI, March 30, 2016. [ML16069A084]

³ FMRI, to U.S. Nuclear Regulatory Commission, June 10, 2016. ML16166A041]

⁴ Matthew Meyer, U.S. Nuclear Regulatory Commission, to Robert Compennolle, FMRI, September 2, 2016. [ML16236A383]

Source Term

Configuration

The configuration and principal radionuclides described in the DP were not changed for this revision of the DCGLs.

Chemical Form

The RESRAD address chemical form by means of the parameter Transport Distribution coefficient (labeled partition coefficient in the DP and applicable guidance). The values assigned in the Table 5-5 of the DP for the transport distribution coefficients could not be reproduced from the reference provided therein as "NUREG/CR-5512, Vol. 3". Therefore FMRI identified a transport distribution coefficient value for each radionuclide from applicable guidance⁵; the values are provided in Table 2.

Residual Radioactivity Spatial Distribution

The residual radioactivity spatial distribution described in the DP was not changed for this revision of the DCGLs.

Critical Group, Scenario, and Pathways Identification and Selection

Scenario Identification

The scenario identification described in the DP was not changed for this revision of the DCGLs.

Critical Group Determination

The critical group described in the DP was not changed for this revision of the DCGLs.

Exposure Pathways

The exposure pathways described in the DP were not changed for this revision of the DCGLs expect that the drinking water pathway was activated. The exposure pathway selections are identified in Table 1. The drinking water pathway was modeled by assuming all on site drinking water is from a groundwater well on site for which the water has become contaminated by the residual radioactivity in soil, represented by the DCGLs; the associated model parameters and a brief basis for respective value are provided in Table 2.

⁵ U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000. [Table 3.9-1]

The DP at Table 5-3 identified key parameters of the scenario and provided a respective value. The following changes were made for the revised DCGLs:

- Exposure duration was changed from 25 years to one year to reflect the actual compliance period. This parameter is used only for risk calculations, not for dose calculations.
- Inhalation (breathing) rate was changed from 11,400 m³/yr to 8400 m³/y to reflect use of the “most likely” value provided by guidance.⁶
- Soil ingestion was changed from 18.25/yr to 18.3 m³/y to reflect use of the “most likely” value provided by guidance.³
- Drinking water intake was changed from “Not used” to 250 L/y to reflect a reasonable intake for time at work. Derivation of the intake rate is provided with Table 2 at footnote 5.

Conceptual Model

The conceptual model described in the DP was not changed for this revision of the DCGLs.

Relative Location and Activities of the Critical Group

The relative location and activities of the critical group described in the DP were not changed for this revision of the DCGLs. These conditions were particularly reviewed previously and found acceptable.⁷

Hydrologic and Environmental Transport Processes

The hydrologic and environmental transport process parameters described in the DP were changed for this revision of the DCGLs in order to reflect activation of the drinking water pathway. Particularly, a saturated zone was automatically added to the model. Additionally, an uncontaminated unsaturated zone was also included. The associated model parameters and a brief basis for respective value are provided in Table 2.

Dimensions, Location, and Spatial Variability of the Source Term

The dimensions, location, and spatial variability of the source term described in the DP were not changed for this revision of the DCGLs.

Calculations and Input Parameters

The calculations described in the DP were not changed for this revision of the DCGLs; i.e., this revision of the DCGLs used RESRAD Version 6.2.1, deterministic mode.

⁶ ibid [page 5-19]

⁷ U.S. Nuclear Regulatory Commission. Safety Evaluation Report for License Amendment Application to Approve Decommissioning. October 31, 2003. [ML033250083]

Input Parameters

The DP at tables 5-4, 5-5, and 5-6 identified parameters of the scenario and provided a respective value. The following changes were made for the revised DCGLs:

- The values for the following were changed because the source (reference) for the original value could not be reproduced or recreated:
 - Transport distribution coefficients as discussed above at Chemical Form:
 - Uranium from $2.18 \text{ cm}^3/\text{g}$ to $126 \text{ cm}^3/\text{g}$, then to $15 \text{ cm}^3/\text{g}$ as a result of Sensitivity Analyses (Attachment 2).
 - Thorium from $119 \text{ cm}^3/\text{g}$ to $5884 \text{ cm}^3/\text{g}$.
 - Radium from $3530 \text{ cm}^3/\text{g}$ to $3533 \text{ cm}^3/\text{g}$.
 - Lead from $2380 \text{ cm}^3/\text{g}$ to $2392 \text{ cm}^3/\text{g}$.
 - Protactinium from $4.8 \text{ cm}^3/\text{g}$ to $380 \text{ cm}^3/\text{g}$, then to $43 \text{ cm}^3/\text{g}$ as a result of Sensitivity Analyses (Attachment 2).
 - Actinium from $1739 \text{ cm}^3/\text{g}$ to $825 \text{ cm}^3/\text{g}$.
 - Length parallel to aquifer flow from 275 m to 239 m.
- The DP at Section 3.5.2 Site Geology describes the natural soils at the site to be predominantly composed of “silty and sandy clay, ...”. This description was used to choose values for the following (see Table 2):
 - Density of contaminated zone from 1.51 g/cm^3 to 1.67 g/cm^3 .
 - Contaminated zone total porosity from 0.44 to 0.37.
 - Contaminated zone field capacity to 0.38.
 - Contaminated zone hydraulic conductivity from 5500 m/y to 0.94 m/y.
 - Contaminated zone b parameter from 4.05 to 8.25

 - Density of Unsaturated Zone 1 to 1.67 g/cm^3 .
 - Unsaturated Zone 1 total porosity 0.37.
 - Unsaturated Zone 1 effective porosity to 0.29.
 - Unsaturated Zone 1 field capacity to 0.38.
 - Unsaturated Zone 1 hydraulic conductivity to 0.94 m/y.
 - Unsaturated Zone 1 b parameter to 8.25.
- The DP at Section 3.5.2 Site Geology describes the saturated soils at the site to be sand. This description was used to choose values for the following (see Table 2):
 - Density of saturated zone to 1.51 g/cm^3 .
 - Saturated zone total porosity 0.43.
 - Saturated zone effective porosity to 0.38.
 - Saturated zone field capacity to 0.1.
 - Saturated zone hydraulic conductivity to 2506 m/y.
 - Saturated zone hydraulic gradient to 0.027.

- The DP at Section 3.5.2 Site Geology describes the unconsolidated soils at the site to range from 8.75 feet to 34.5 feet; a simple average is 21.6 feet (6.5m). The same section describes the saturated soils to range in thickness from 1.5 to 17.5 feet; a simple average is 9.5 feet (2.9m). Then the average uncontaminated unsaturated zone is construed to be the unconsolidated thickness minus each of the average contaminated thickness (0.85m) and the average saturated thickness (2.9m), or 2.75m.

Well pump intake depth is assumed to be the completion depth of a well through the average unconsolidated thickness of 6.5m.

- The following were developed to represent local conditions (see Table 2):
 - Evapotranspiration coefficient from 0.99 to 0.625.
 - Wind speed (Average Annual) from 4.52 m/s to 3.2 m/s.
 - Precipitation from 1.1 m/y to 1.19 m/y.
- The following were taken from guidance to represent most likely values (see Table 2):
 - Mass loading for inhalation from 0.0001 g/m³ to 0.00023 g/m³.
 - Indoor dust filtration factor (Shielding Factor, Inhalation) from 0.4 to 0.58.
 - External gamma shielding factor (Shielding Factor, External Gamma) from 0.552 to 0.27.

All of the parameters used by the RESRAD to evaluate the industrial worker scenario are listed in Table 2 along with the respective value and a basis for choice of the value.

Results

The result of the dose assessment determining the DGCLs as Attachment 1 as a copy of the RESRAD Summary Report.

Compliance with Regulatory Criteria

Compliance with the criteria will be demonstrated by application of DCGLs in conformance with the sum-of-fractions (unity or mixture) rule. The DCGLs are listed in Table 3.

Sensitivity Analysis

A sensitivity analysis was carried out of the scenario by taking individual parameters and repeating the RESRAD calculation with the respective parameter under test set at two specified extremes. Only a single test parameter is varied at a time. The annual dose was found to be significantly sensitive to two evaluated parameters; the transport distribution coefficient for uranium (126 ml/g) and the transport distribution coefficient for protactinium (380 ml/g). Then the revised DCGLs were determined using the 25th percentile value of the transport distribution coefficient for uranium of 15 ml/g and the 25th percentile value of the transport distribution coefficient for protactinium of 43 ml/g. The results of the sensitivity analysis of the industrial worker scenario are presented in Attachment 2.

TABLE 1
INDUSTRIAL WORKER SCENARIO
EXPOSURE PATHWAY SELECTIONS

PATHWAY ¹	SELECTION
External Gamma	Active
Inhalation (w/o radon)	Active
Plant Ingestion	Suppressed
Meat Ingestion	Suppressed
Milk Ingestion	Suppressed
Aquatic Foods	Suppressed
Drinking Water	Active
Soil Ingestion	Active
Radon	Suppressed

¹ These pathways match those available from the conceptual model used in the dose assessment; i.e. RESRAD version 6.21.

TABLE 2
INDUSTRIAL WORKER SCENARIO
FMRI SELECTED MODEL VALUES

Parameter	FMRI Value	Basis for Value
Source (Soil Concentrations)		
Activity	pCi	
Dose	mrem	
Basic radiation dose limit (mrem/yr)	25	10 CFR 20.1402 Radiological criteria for unrestricted use
Nuclide concentration for U-238 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for U-238		
Contaminated zone (cm ³ /g)	15	Original value 126 from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm ³ /g)	15	Adjusted to 25 th percentile based on results of sensitivity analysis (see Attachment 2).
Saturated zone (cm ³ /g)	15	
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement</i> = 0. ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹
Nuclide concentration for U-235 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for U-235		
Contaminated zone (cm ³ /g)	15	Original value 126 from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm ³ /g)	15	Adjusted to 25 th percentile based on results of sensitivity analysis (see Attachment 2).
Saturated zone (cm ³ /g)	15	
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement</i> = 0. ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹
Nuclide concentration for Pa-231 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for Pa-231		
Contaminated zone (cm ³ /g)	43	Original value 126 from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm ³ /g)	43	Adjusted to 25 th percentile based on results of sensitivity analysis (see Attachment 2).
Saturated zone (cm ³ /g)	43	
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement</i> = 0. ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹
Nuclide concentration for Ac-227 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for Ac-227		
Contaminated zone (cm ³ /g)	825	Suggestion from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm ³ /g)	825	Suggestion from guidance for use of RESRAD. ²
Saturated zone (cm ³ /g)	825	Suggestion from guidance for use of RESRAD. ²
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement</i> = 0. ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹

TABLE 2
INDUSTRIAL WORKER SCENARIO
FMRI SELECTED MODEL VALUES

Parameter	FMRI Value	Basis for Value
Nuclide concentration for Th-232 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for Th-232		
Contaminated zone (cm**3/g)	5884	Suggestion from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm**3/g)	5884	Suggestion from guidance for use of RESRAD. ²
Saturated zone (cm**3/g)	5884	Suggestion from guidance for use of RESRAD. ²
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement = 0</i> . ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹
Nuclide concentration for Ra-228 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for Ra-228		
Contaminated zone (cm**3/g)	3533	Suggestion from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm**3/g)	3533	Suggestion from guidance for use of RESRAD. ²
Saturated zone (cm**3/g)	3533	Suggestion from guidance for use of RESRAD. ²
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement = 0</i> . ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹
Nuclide concentration for Th-228 (pCi/g)		To be determined for the <i>Basic radiation dose limit</i> .
Transport Distribution coefficients for Th-228		
Contaminated zone (cm**3/g)	5884	Suggestion from guidance for use of RESRAD. ²
Unsaturated zone 1 (cm**3/g)	5884	Suggestion from guidance for use of RESRAD. ²
Saturated zone (cm**3/g)	5884	Suggestion from guidance for use of RESRAD. ²
Time since material placement (yr)	0	RESRAD default. ¹
Groundwater concentration (pCi/L)	---	Not available; reflects <i>Time since material placement = 0</i> . ¹
Solubility Limit (mol/L)	0	RESRAD default. ¹
Leach Rate (/yr)	0	RESRAD default. ¹
Calculation Parameters (Times)		
Times for Calculations (years)	1	RESRAD default. ¹
Times for Calculations (years)	3	RESRAD default. ¹
Times for Calculations (years)	10	RESRAD default. ¹
Times for Calculations (years)	30	RESRAD default. ¹
Times for Calculations (years)	100	RESRAD default. ¹
Times for Calculations (years)	300	RESRAD default. ¹
Times for Calculations (years)	1000	RESRAD default and 10 CFR 20.1401(d)

**TABLE 2
INDUSTRIAL WORKER SCENARIO
FMRI SELECTED MODEL VALUES**

Parameter	FMRI Value	Basis for Value
Contaminated Zone Parameters		
Area of contaminated zone (m**2)	180000	Decommissioning Plan, Section 5.2.1.
Thickness of contaminated zone (m)	0.85	Decommissioning Plan, Section 5.2.1.
Length parallel to aquifer flow (m)	239	Diameter of a circle of <i>Area of contaminated zone</i> .
Cover ... Contaminated Zone Hydrological Data		
Cover depth (m)	0	No clean cover of surface soils.
Density of cover material (g/cm**3)	---	Not available; reflects <i>Cover depth</i> = 0. ¹
Cover erosion rate (m/yr)	---	Not available; reflects <i>Cover depth</i> = 0. ¹
Density of contaminated zone (g/cm**3)	1.67	An average of means for sandy clay and silty clay. ²
Contaminated zone erosion rate (m/yr)	0.00006	Recommendation from guidance for use of RESRAD. ²
Contaminated zone total porosity	0.37	An average of means for sandy clay and silty clay. ²
Contaminated zone field capacity	0.38	An average of means for sandy clay and silty clay. ⁶
Contaminated ... hydraulic conductivity (m/yr)	0.94	An average of means for sandy clay and silty clay. ²
Contaminated zone b parameter	8.25	An average of means for sandy clay and silty clay. ²
Humidity in air (g/cm**3)	---	Not available due suppressed radon pathway. ¹
Evapotranspiration coefficient	0.645	Site-specific estimate. ³
Wind Speed (m/sec)	3.2	Site-specific estimate. ⁴
Precipitation (m/yr)	1.19	Site-specific estimate. ⁴
Irrigation (m/yr)	0	Not applicable.
Irrigation mode	---	Not applicable.
Runoff coefficient	0.4	Estimate from guidance for use of RESRAD. ²
Watershed ... nearby stream or pond (m**2)	180000	Site-specific estimate as <i>Area of contaminated zone</i> .
Accuracy for water/soil computations	0.001	RESRAD default. ¹
Saturated Zone Hydrological Data		
Density of saturated zone (g/cm**3)	1.51	A mean for sand. ²
Saturated zone total porosity	0.43	A mean for sand. ²
Saturated zone effective porosity	0.38	A mean for sand. ²
Saturated zone field capacity	0.1	Recommendation from guidance for use of RESRAD. ⁶
Saturated zone hydraulic conductivity (m/yr)	2506	A probability of 0.5 (50%) for sand. ²
Saturated zone hydraulic gradient	0.027	A mean for sand and gravel. ²
Saturated zone b parameter	---	Not available; reflects <i>water table drop rate</i> equal zero ¹
Water table drop rate (m/yr)	0	Recognize unconfined groundwater system.
Well pump intake depth	6.5	Site-specific estimate as an average. ¹
Model for Water Transport Parameters		
Nondispersion (ND) or Mass-Balance (MB)	ND	RESRAD default based on size of contaminated area. ¹
Well pumping rate (m**3/yr)	250	RESRAD default. ¹

TABLE 2
INDUSTRIAL WORKER SCENARIO
FMRI SELECTED MODEL VALUES

Parameter	FMRI Value	Basis for Value
Uncontaminated Unsaturated Zone Parameters		
Unsaturated Zones	1	Recognize actual site condition.
Unsaturated Zone 1, Thickness (m)	2.75	Site-specific estimate as an average. ¹
Unsaturated Zone 1, Density (g/cm ³)	1.67	An average of means for sandy clay and silty clay. ²
Unsaturated Zone 1, Total Porosity	0.37	An average of means for sandy clay and silty clay. ²
Unsaturated Zone 1, Effective Porosity	0.29	An average of means for sandy clay and silty clay. ²
Unsaturated zone field capacity	0.38	An average of means for sandy clay and silty clay. ⁶
Saturated zone hydraulic conductivity (m/yr)	0.94	An average of means for sandy clay and silty clay. ²
Unsaturated Zone 1, b Parameter	8.25	An average of means for sandy clay and silty clay. ²
Occupancy, Inhalation, ... External Gamma Data		
Inhalation rate (m ³ /yr)	8400	Recommendation from guidance for use of RESRAD. ²
Mass loading for inhalation (g/m ³)	0.00023	Estimate median from guidance for RESRAD of PM-10. ²
Exposure duration	1y	Reflects applicable compliance period.
Indoor dust filtration factor	0.58	Estimate from guidance for RESRAD of daytime PM-10. ²
External gamma shielding factor	0.27	A mean value from guidance for use of RESRAD. ²
Indoor time fraction	0.17	Decommissioning Plan, Section 5.2.1.
Outdoor time fraction	0.06	Decommissioning Plan, Section 5.2.1.
Shape of the contaminated zone	circular	Assumed shape of <i>Area of contaminated zone</i> .
Ingestion Pathway, Dietary Data		
Fruits, vegetables, grain consumption (kg/yr)	---	Not available due suppressed plant ingestion pathway. ¹
Leafy vegetable consumption (kg/yr)	---	Not available due suppressed plant ingestion pathway. ¹
Milk consumption (L/yr)	---	Not available due suppressed milk ingestion pathway. ¹
Meat and poultry consumption (kg/yr)	---	Not available due suppressed meat ingestion pathway. ¹
Fish consumption (kg/yr)	---	Not available due suppressed aquatic ... ingestion pathway. ¹
Other seafood consumption	---	Not available due suppressed aquatic ... ingestion pathway. ¹
Soil ingestion (g/yr)	18.3	Suggestion from guidance for use of RESRAD. ²
Drinking water intake (L/yr)	250	A reasonable estimate for time at work. ⁵
Contaminated fraction Drinking water	1	A conservative assumption.
Contaminated fraction Household water	---	Not available due suppressed radon pathway. ¹
Contaminated fraction Livestock water	---	Not available due suppressed meat ingestion pathway. ¹
Contaminated fraction Irrigation water	---	Not available due suppressed plant ingestion pathway. ¹
Contaminated fraction Aquatic food	---	Not available due suppressed aquatic ... ingestion pathway. ¹
Contaminated fraction Plant food	---	Not available due suppressed plant ingestion pathway. ¹
Contaminated fraction Meat	---	Not available due suppressed meat ingestion pathway. ¹
Contaminated fraction Milk	---	Not available due suppressed milk ingestion pathway. ¹

TABLE 2
INDUSTRIAL WORKER SCENARIO
FMRI SELECTED MODEL VALUES

Parameter	FMRI Value	Basis for Value
Ingestion Pathway, Nondietary Data		
Livestock fodder intake for meat (kg/day)	---	Not available due suppressed meat ingestion pathway. ¹
Livestock fodder intake for milk (kg/day)	---	Not available due suppressed milk ingestion pathway. ¹
Livestock water intake for meat (L/day)	---	Not available due suppressed meat ingestion pathway. ¹
Livestock water intake for milk (L/day)	---	Not available due suppressed milk ingestion pathway. ¹
Livestock soil intake (kg/day)	---	Not available due suppressed meat and milk ingestion pathways. ¹
Mass loading for foliar deposition (g/m**3)	---	Not available due suppressed meat and milk ingestion pathways. ¹
Depth of soil mixing layer (m)	0.15	RESRAD default. ¹
Depth of roots (m)	---	Not available due suppressed meat and milk ingestion pathways. ¹
Groundwater Fractional Usage Drinking water	1	No potable surface water available on site.
Groundwater fractional Usage Household ...	---	Not available due suppressed radon pathway. ¹
Groundwater Fractional Usage Livestock ...	---	Not available due suppressed meat and milk ingestion pathways. ¹
Groundwater Fractional Usage Irrigation ...	---	Not available due suppressed meat and milk ingestion pathways. ¹
Plant Factors		
All	---	Not available due suppressed ingestion pathways. ¹

¹ Yu, C., et. al. "User's Manual for RESRAD Version 6" Argonne, IL: Argonne National Laboratory. ANL/EAD-4. July 2001.

² U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

³ Sanford, W. E. and Selnick, D. L. (2013), Estimation of Evapotranspiration Across the Conterminous United States Using a Regression With Climate and Land-Cover Data. JAWRA Journal of the American Water Resources Association, 49: 217–230. doi: 10.1111/jawr.12010 [Figure 13; average for Muskogee County.]

⁴ http://climate.ok.gov/county_climate/Products/County_Climatologies/county_climate_muskogee.pdf

⁵ Two liters per day* adjusted for 250 workdays per year and one-half of daily intake at work. *40 CFR 141.66(d)(2)

⁶ Yu, C., et. al. "Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil and Building Structures" Argonne, IL: Argonne National Laboratory. ANL/EVS/TM-14/4. September 2015.

⁷ Fansteel. "Decommissioning Plan, Fansteel, Muskogee, Oklahoma Site", Rev. 0. January 14, 2003. [ML030240051] {Section 3.5.2.}

TABLE 3
DERIVED CONCENTRATION GUIDELINE LEVELS
(DCGL)

Radionuclide	DCGL pCi/g
U-238 + D	61.0
U-234	58.1
U-235 + D	59.9
Pa-231	4.2
Ac-227 + D	39.0
Th-232	13.8
Th-230	58.8
Th-228 + D	27.5
Ra-226 + D	21.3
Ra-228 + D	24.5
Pb-210 + D	780

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Total Dose Components	
Time = 0.000E+00	13
Time = 1.000E+00	14
Time = 3.000E+00	15
Time = 1.000E+01	16
Time = 3.000E+01	17
Time = 1.000E+02	18
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Dose Conversion Factor (and Related) Parameter Summary
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Menu	Parameter	Current Value	Default	Parameter Name
3-1	Dose conversion factors for inhalation, mrem/pCi:			
3-1	Ac-227+D	6.720E+00	6.720E+00	DCF2(1)
3-1	Pa-231	1.280E+00	1.280E+00	DCF2(2)
3-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(3)
3-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(4)
3-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(5)
3-1	Th-228+D	3.450E-01	3.450E-01	DCF2(6)
3-1	Th-230	3.260E-01	3.260E-01	DCF2(7)
3-1	Th-232	1.640E+00	1.640E+00	DCF2(8)
3-1	U-234	1.320E-01	1.320E-01	DCF2(9)
3-1	U-235+D	1.230E-01	1.230E-01	DCF2(10)
3-1	U-238+D	1.180E-01	1.180E-01	DCF2(11)
3-1	Dose conversion factors for ingestion, mrem/pCi:			
3-1	Ac-227+D	1.480E-02	1.480E-02	DCF3(1)
3-1	Pa-231	1.060E-02	1.060E-02	DCF3(2)
3-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(3)
3-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(4)
3-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(5)
3-1	Th-228+D	8.080E-04	8.080E-04	DCF3(6)
3-1	Th-230	5.480E-04	5.480E-04	DCF3(7)
3-1	Th-232	2.730E-03	2.730E-03	DCF3(8)
3-1	U-234	2.830E-04	2.830E-04	DCF3(9)
3-1	U-235+D	2.670E-04	2.670E-04	DCF3(10)
3-1	U-238+D	2.690E-04	2.690E-04	DCF3(11)
3-34	Food transfer factors:			
3-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(1,1)
3-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,2)
3-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,3)
3-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(2,1)
3-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF(2,2)
3-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(2,3)
3-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(3,1)
3-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(3,2)
3-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(3,3)
3-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(4,1)
3-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(4,2)
3-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(4,3)
3-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(5,1)
3-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(5,2)
3-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(5,3)
3-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(6,1)
3-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(6,2)
3-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(6,3)

Dose Conversion Factor (and Related) Parameter Summary (continued)
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Menu	Parameter	Current Value	Default	Parameter Name
>-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(7,1)
>-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(7,2)
>-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(7,3)
>-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(8,1)
>-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(8,2)
>-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(8,3)
>-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(9,1)
>-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(9,2)
>-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(9,3)
>-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(10,1)
>-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(10,2)
>-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(10,3)
>-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(11,1)
>-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(11,2)
>-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(11,3)
>-5	Bioaccumulation factors, fresh water, L/kg:			
>-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC(1,1)
>-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(1,2)
>-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC(2,1)
>-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC(2,2)
>-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(3,1)
>-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(3,2)
>-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(4,1)
>-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(4,2)
>-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(5,1)
>-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(5,2)
>-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(6,1)
>-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(6,2)
>-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(7,1)
>-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(7,2)
>-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(8,1)
>-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(8,2)
>-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(9,1)
>-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(9,2)
>-5	U-235+D , fish	1.000E+01	1.000E+01	BIOFAC(10,1)
>-5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(10,2)

Dose Conversion Factor (and Related) Parameter Summary (continued)
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Menu	Parameter	Current Value	Default	Parameter Name
>5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(11,1)
>5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(11,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.800E+05	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	8.500E-01	2.000E+00	---	THICKO
R011	Length parallel to aquifer flow (m)	2.390E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	2.500E+01	2.500E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ac-227	1.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Pa-231	1.000E+00	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Pb-210	1.000E+00	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Ra-226	1.000E+00	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Ra-228	1.000E+00	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Th-228	1.000E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): Th-230	1.000E+00	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Th-232	1.000E+00	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): U-234	1.000E+00	0.000E+00	---	S1(9)
R012	Initial principal radionuclide (pCi/g): U-235	1.000E+00	0.000E+00	---	S1(10)
R012	Initial principal radionuclide (pCi/g): U-238	1.000E+00	0.000E+00	---	S1(11)
R012	Concentration in groundwater (pCi/L): Ac-227	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Pa-231	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Ra-228	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Th-228	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(9)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(10)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(11)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVERO
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.670E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	6.000E-05	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	3.700E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	3.800E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	9.400E-01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	8.250E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	3.200E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	6.450E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.190E+00	1.000E+00	---	PRECIP

Site-Specific Parameter Summary (continued)

fenu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
\013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
\013	Irrigation mode	overhead	overhead	---	IDITCH
\013	Runoff coefficient	4.000E-01	2.000E-01	---	RUNOFF
\013	Watershed area for nearby stream or pond (m**2)	1.800E+05	1.000E+06	---	WAREA
\013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
\014	Density of saturated zone (g/cm**3)	1.510E+00	1.500E+00	---	DENSAQ
\014	Saturated zone total porosity	4.300E-01	4.000E-01	---	TPSZ
\014	Saturated zone effective porosity	3.800E-01	2.000E-01	---	EPSZ
\014	Saturated zone field capacity	1.000E-01	2.000E-01	---	FCSZ
\014	Saturated zone hydraulic conductivity (m/yr)	2.506E+03	1.000E+02	---	HCSZ
\014	Saturated zone hydraulic gradient	2.700E-02	2.000E-02	---	HGWT
\014	Saturated zone b parameter	not used	5.300E+00	---	BSZ
\014	Water table drop rate (m/yr)	0.000E+00	1.000E-03	---	VWT
\014	Well pump intake depth (m below water table)	6.500E+00	1.000E+01	---	DWIBWT
\014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
\014	Well pumping rate (m**3/yr)	not used	2.500E+02	---	UW
\015	Number of unsaturated zone strata	1	1	---	NS
\015	Unsat. zone 1, thickness (m)	2.750E+00	4.000E+00	---	H(1)
\015	Unsat. zone 1, soil density (g/cm**3)	1.670E+00	1.500E+00	---	DENSUZ(1)
\015	Unsat. zone 1, total porosity	3.700E-01	4.000E-01	---	TPUZ(1)
\015	Unsat. zone 1, effective porosity	2.900E-01	2.000E-01	---	EPUZ(1)
\015	Unsat. zone 1, field capacity	3.800E-01	2.000E-01	---	FCUZ(1)
\015	Unsat. zone 1, soil-specific b parameter	8.250E+00	5.300E+00	---	BUZ(1)
\015	Unsat. zone 1, hydraulic conductivity (m/yr)	9.400E-01	1.000E+01	---	HCUZ(1)
\016	Distribution coefficients for Ac-227				
\016	Contaminated zone (cm**3/g)	8.250E+02	2.000E+01	---	DCNUCC(1)
\016	Unsat. zone 1 (cm**3/g)	8.250E+02	2.000E+01	---	DCNUCU(1,1)
\016	Saturated zone (cm**3/g)	8.250E+02	2.000E+01	---	DCNUCS(1)
\016	Leach rate (/yr)	0.000E+00	0.000E+00	2.164E-04	ALEACH(1)
\016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
\016	Distribution coefficients for Pa-231				
\016	Contaminated zone (cm**3/g)	4.300E+01	5.000E+01	---	DCNUCC(2)
\016	Unsat. zone 1 (cm**3/g)	4.300E+01	5.000E+01	---	DCNUCU(2,1)
\016	Saturated zone (cm**3/g)	4.300E+01	5.000E+01	---	DCNUCS(2)
\016	Leach rate (/yr)	0.000E+00	0.000E+00	4.131E-03	ALEACH(2)
\016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
\016	Distribution coefficients for Pb-210				
\016	Contaminated zone (cm**3/g)	2.392E+03	1.000E+02	---	DCNUCC(3)
\016	Unsat. zone 1 (cm**3/g)	2.392E+03	1.000E+02	---	DCNUCU(3,1)
\016	Saturated zone (cm**3/g)	2.392E+03	1.000E+02	---	DCNUCS(3)
\016	Leach rate (/yr)	0.000E+00	0.000E+00	7.464E-05	ALEACH(3)
\016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)

Site-Specific Parameter Summary (continued)

ISNU	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
0016	Distribution coefficients for Ra-226				
0016	Contaminated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCC(4)
0016	Unsaturated zone 1 (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCU(4,1)
0016	Saturated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCS(4)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	5.054E-05	ALEACH(4)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
0016	Distribution coefficients for Ra-228				
0016	Contaminated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCC(5)
0016	Unsaturated zone 1 (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCU(5,1)
0016	Saturated zone (cm**3/g)	3.533E+03	7.000E+01	---	DCNUCS(5)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	5.054E-05	ALEACH(5)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
0016	Distribution coefficients for Th-228				
0016	Contaminated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCC(6)
0016	Unsaturated zone 1 (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCU(6,1)
0016	Saturated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCS(6)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	3.035E-05	ALEACH(6)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
0016	Distribution coefficients for Th-230				
0016	Contaminated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCC(7)
0016	Unsaturated zone 1 (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCU(7,1)
0016	Saturated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCS(7)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	3.035E-05	ALEACH(7)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
0016	Distribution coefficients for Th-232				
0016	Contaminated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCC(8)
0016	Unsaturated zone 1 (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCU(8,1)
0016	Saturated zone (cm**3/g)	5.884E+03	6.000E+04	---	DCNUCS(8)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	3.035E-05	ALEACH(8)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)
0016	Distribution coefficients for U-234				
0016	Contaminated zone (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCC(9)
0016	Unsaturated zone 1 (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCU(9,1)
0016	Saturated zone (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCS(9)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	1.173E-02	ALEACH(9)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(9)
0016	Distribution coefficients for U-235				
0016	Contaminated zone (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCC(10)
0016	Unsaturated zone 1 (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCU(10,1)
0016	Saturated zone (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCS(10)
0016	Leach rate (/yr)	0.000E+00	0.000E+00	1.173E-02	ALEACH(10)
0016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
\016	Distribution coefficients for U-238				
\016	Contaminated zone (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCC(11)
\016	Unsaturated zone 1 (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCU(11,1)
\016	Saturated zone (cm**3/g)	1.500E+01	5.000E+01	---	DCNUCS(11)
\016	Leach rate (/yr)	0.000E+00	0.000E+00	1.173E-02	ALEACH(11)
\016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
\017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
\017	Mass loading for inhalation (g/m**3)	2.300E-04	1.000E-04	---	MLINH
\017	Exposure duration	1.000E+00	3.000E+01	---	ED
\017	Shielding factor, inhalation	5.800E-01	4.000E-01	---	SHF3
\017	Shielding factor, external gamma	2.700E-01	7.000E-01	---	SHF1
\017	Fraction of time spent indoors	1.700E-01	5.000E-01	---	FIND
\017	Fraction of time spent outdoors (on site)	6.000E-02	2.500E-01	---	FOTD
\017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
\017	Radii of shape factor array (used if FS = -1):				
\017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
\017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
\017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
\017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
\017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
\017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
\017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
\017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
\017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
\017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
\017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
\017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
\017	Fractions of annular areas within AREA:				
\017	Ring 1	not used	1.000E+00	---	FRACA(1)
\017	Ring 2	not used	2.732E-01	---	FRACA(2)
\017	Ring 3	not used	0.000E+00	---	FRACA(3)
\017	Ring 4	not used	0.000E+00	---	FRACA(4)
\017	Ring 5	not used	0.000E+00	---	FRACA(5)
\017	Ring 6	not used	0.000E+00	---	FRACA(6)
\017	Ring 7	not used	0.000E+00	---	FRACA(7)
\017	Ring 8	not used	0.000E+00	---	FRACA(8)
\017	Ring 9	not used	0.000E+00	---	FRACA(9)
\017	Ring 10	not used	0.000E+00	---	FRACA(10)
\017	Ring 11	not used	0.000E+00	---	FRACA(11)
\017	Ring 12	not used	0.000E+00	---	FRACA(12)
\018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
\018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
\018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
\018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
\018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
\018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
\018	Soil ingestion rate (g/yr)	1.830E+01	3.650E+01	---	SOIL
\018	Drinking water intake (L/yr)	2.500E+02	5.100E+02	---	DWI

Site-Specific Parameter Summary (continued)

Item	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
\018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
\018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
\018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
\018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
\018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
\018	Contamination fraction of plant food	not used	-1	---	FPLANT
\018	Contamination fraction of meat	not used	-1	---	FMEAT
\018	Contamination fraction of milk	not used	-1	---	FMILK
\019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
\019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
\019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
\019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
\019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
\019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
\019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
\019	Depth of roots (m)	not used	9.000E-01	---	DROOT
\019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
\019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
\019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
\019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
\19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
\19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
\19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
\19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
\19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
\19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
\19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
\19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
\19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
\19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
\19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
\19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
\19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
\19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
\19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
\19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
\14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
\14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
\14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
\14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
\14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
\14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
\14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
\14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
\14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
\14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
\TOR	Storage times of contaminated foodstuffs (days):				

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
Ø21	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
Ø21	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
Ø21	Total porosity of the cover material	not used	4.000E-01	---	TPCV
Ø21	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
Ø21	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
Ø21	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
Ø21	Diffusion coefficient for radon gas (m/sec):				
Ø21	in cover material	not used	2.000E-06	---	DIFCV
Ø21	in foundation material	not used	3.000E-07	---	DIFFL
Ø21	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
Ø21	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
Ø21	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
Ø21	Height of the building (room) (m)	not used	2.500E+00	---	HRM
Ø21	Building interior area factor	not used	0.000E+00	---	FAI
Ø21	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
Ø21	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
Ø21	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
ITL	Number of graphical time points	32	---	---	NPTS
ITL	Maximum number of integration points for dose	17	---	---	LYMAX
ITL	Maximum number of integration points for risk	1	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	180000.00 square meters	Ac-227	1.000E+00
Thickness:	0.85 meters	Pa-231	1.000E+00
Soil Depth:	0.00 meters	Pb-210	1.000E+00
		Ra-226	1.000E+00
		Ra-228	1.000E+00
		Th-228	1.000E+00
		Th-230	1.000E+00
		Th-232	1.000E+00
		U-234	1.000E+00
		U-235	1.000E+00
		U-238	1.000E+00

Total Dose TDOSE(t), mrem/yr

Basic Radiation Dose Limit = 2.500E+01 mrem/yr

Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	3.949E+00	3.946E+00	3.941E+00	3.923E+00	3.863E+00	3.643E+00	4.353E+00	5.742E+00
M(t):	1.579E-01	1.578E-01	1.577E-01	1.569E-01	1.545E-01	1.457E-01	1.741E-01	2.297E-01
Maximum TDOSE(t):	8.933E+00 mrem/yr	at t =	817 ± 2 years					

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)

As mrem/yr and Fraction of Total Dose At t = 8.172E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio- Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ac-227	8.742E-13	0.0000	1.571E-12	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.586E-13	0.0000
Pa-231	8.729E-03	0.0010	1.689E-02	0.0019	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.879E-03	0.0004
Pb-210	5.585E-15	0.0000	1.126E-14	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.639E-13	0.0000
Ra-226	7.855E-01	0.0879	1.217E-03	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.465E-02	0.0028
Ra-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-228	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	3.357E-01	0.0376	1.828E-02	0.0020	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.234E-02	0.0014
Th-232	1.642E+00	0.1838	1.093E-01	0.0122	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.044E-02	0.0023
J-234	2.351E-04	0.0000	1.454E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.852E-06	0.0000
J-235	2.973E-05	0.0000	4.751E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.088E-05	0.0000
J-238	1.134E-06	0.0000	4.582E-07	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.943E-08	0.0000
Total	2.772E+00	0.3103	1.458E-01	0.0163	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.133E-02	0.0069

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 8.172E+02 years
Water Dependent Pathways

[illegible]

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
 Basic Radiation Dose Limit = 2.500E+01 mrem/yr

Radionuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
C-227	3.901E+01	4.028E+01	4.294E+01	5.374E+01	1.020E+02	9.619E+02	5.849E+05	*7.230E+13
Pa-231	1.704E+02	1.505E+02	1.232E+02	8.025E+01	5.044E+01	4.545E+01	9.898E+01	8.914E+00
Pb-210	7.800E+02	8.047E+02	8.564E+02	1.065E+03	1.986E+03	1.759E+04	8.944E+06	*7.631E+13
La-226	2.132E+01	2.132E+01	2.130E+01	2.127E+01	2.128E+01	2.181E+01	2.399E+01	3.366E+01
La-228	3.289E+01	2.680E+01	2.454E+01	4.173E+01	4.391E+02	2.035E+06	*2.726E+14	*2.726E+14
Th-228	2.750E+01	3.951E+01	8.156E+01	1.030E+03	1.447E+06	*8.192E+14	*8.192E+14	*8.192E+14
Th-230	1.188E+03	1.160E+03	1.108E+03	9.571E+02	6.891E+02	3.502E+02	1.513E+02	5.883E+01
Th-232	1.697E+02	9.977E+01	5.093E+01	2.097E+01	1.423E+01	1.381E+01	1.389E+01	1.419E+01
J-234	2.902E+03	2.936E+03	3.006E+03	3.262E+03	4.122E+03	9.287E+03	6.702E+01	5.880E+04
J-235	2.873E+02	2.906E+02	2.975E+02	3.228E+02	4.071E+02	9.063E+02	6.845E+01	3.160E+03
J-238	1.064E+03	1.076E+03	1.102E+03	1.196E+03	1.512E+03	3.437E+03	7.031E+01	2.717E+05

At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
 and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
 at tmin = time of minimum single radionuclide soil guideline
 and at tmax = time of maximum total dose = 817 ± 2 years

Radionuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
C-227	1.000E+00	0.000E+00	6.409E-01	3.901E+01	2.703E-12	9.247E+12
Pa-231	1.000E+00	817 ± 2	5.963E+00	4.193E+00	5.964E+00	4.192E+00
Pb-210	1.000E+00	0.000E+00	3.205E-02	7.800E+02	2.807E-13	*7.631E+13
La-226	1.000E+00	17.94 ± 0.04	1.176E+00	2.126E+01	8.114E-01	3.081E+01
La-228	1.000E+00	2.719 ± 0.005	1.020E+00	2.450E+01	0.000E+00	*2.726E+14
Th-228	1.000E+00	0.000E+00	9.090E-01	2.750E+01	0.000E+00	*8.192E+14
Th-230	1.000E+00	1.000E+03	4.249E-01	5.883E+01	3.663E-01	6.825E+01
Th-232	1.000E+00	70.0 ± 0.1	1.812E+00	1.380E+01	1.772E+00	1.411E+01
J-234	1.000E+00	287.6 ± 0.6	4.302E-01	5.812E+01	1.108E-03	2.256E+04
J-235	1.000E+00	287.6 ± 0.6	4.173E-01	5.991E+01	1.762E-02	1.419E+03
J-238	1.000E+00	287.6 ± 0.6	4.100E-01	6.097E+01	7.955E-04	3.143E+04

At specific activity limit

ATTACHMENT 2

SENSITIVITY ANALYSES

INDUSTRIAL WORKER SCENARIO

Evaluation of annual dose

SENSITIVITY ANALYSES

Introduction

To ensure that the results of the revised DCGLs are unlikely to significantly underestimate potential dose, the analyses used realistically conservative scenarios and conceptual model. Sensitivity analyses were subsequently completed for which the objective was to identify parameters for which change in value resulted in large change in the calculated dose.

Description

General

The RESRAD parameters available for input to evaluate the industrial worker scenario are listed in Table 1. The parameters evaluated in the sensitivity analyses are marked accordingly in Table 1.

Several parameters, although available to the RESRAD sensitivity analysis, were not evaluated. Each such parameter and the reason it was not evaluated is included in Table 2.

Several parameters were not available to the sensitivity analysis provided by the RESRAD software: they were either turned off by the software based on the active exposure pathways (e.g. "Density of cover material"; there is no cover in the model), or the software did not allow a sensitivity analysis of the parameter due to suppressed pathway (e.g. "Plant Factors"). The parameters not available to the RESRAD sensitivity analysis are listed in Table 3.

The sensitivity analyses were of a deterministic technique; i.e. the change in the output result of peak dose was determined with respect to a change in the independent input parameters. The sensitivity analyses were performed after completing the RESRAD calculations used to determine the DCGLs. The sensitivity analyses were performed by taking each parameter and repeating the RESRAD calculation with the parameter under test set at two previously chosen extremes. The basis for the range over which the sensitivity analyses were completed is indicated or described in Table 4. Only one parameter was varied at a time.

The sensitivity analyses were completed for total dose from summed radionuclides and summed pathways.

Radionuclide Concentrations

The sensitivity analyses were performed against summed radionuclides using an hypothetical source term construed to represent a reasonably conservative as-left condition with regard to concentrations of radionuclides in soil. The hypothetical source term was determined by dividing the DCGL of each radionuclide by the DCGL for Th-232. The hypothetical source term is identified in Table 5. This maintained two fundamental conditions: 1) all of the radionuclides are present for the sensitivity analyses, and 2) the sum-of-fractions compliance is represented. The resulting dose for this modeled condition is 15 mrem/y.

Conclusion

The results of the sensitivity analyses are summarized in Table 6. The annual dose was considered sensitive to a parameter if the annual dose exceeded 25 mrem/y for one of the boundary values of that parameter. The annual dose was found to be significantly sensitive to two evaluated parameters; the transport distribution coefficient for uranium (126 ml/g) and the transport distribution coefficient for protactinium (380 ml/g). Then the revised DCGLs were determined using the 25th percentile value of the transport distribution coefficient for uranium of 15 ml/g and the 25th percentile value of the transport distribution coefficient for protactinium of 43 ml/g.

Table 1
(1 of 2)

**PARAMETERS OF INDUSTRIAL WORKER SCENARIO AVAILABLE FOR
SENSITIVITY ANALYSIS**

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Source	Transport Distribution coefficient: {All zones}	√
	Transport Solubility Limit	
	Transport Leach Rate	
Contaminated Zone	Area of contaminated zone	
	Thickness of contaminated zone	√
	Length parallel to aquifer flow	√
Cover and Contaminated Zone Hydrological Data	Cover depth	
	Density of contaminated zone	√
	Contaminated zone erosion rate	√
	Contaminated zone total porosity	√
	Contaminated zone field capacity	√
	Contaminated zone hydraulic conductivity	√
	Contaminated zone b parameter	√
	Evapotranspiration coefficient	√
	Wind speed	√
	Precipitation	√
	Irrigation	√
	Runoff coefficient	√
	Watershed area for nearby stream or pond	
	Accuracy for soil/water computations	
Saturated Zone Hydrological Data	Density of saturated zone	√
	Saturated zone total porosity	√
	Saturated zone effective porosity	√
	Saturated zone field capacity	√
	Saturated zone hydraulic conductivity	√
	Saturated zone hydraulic gradient	√
	Water table drop rate	
	Well pump intake depth	√
	Well pumping rate	

Table 1
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**PARAMETERS OF INDUSTRIAL WORKER SCENARIO AVAILABLE FOR
SENSITIVITY ANALYSIS**

PARAMETER CATEGORY	PARAMETER DESCRIPTION	SENSITIVITY ANALYSIS PERFORMED
Uncontaminated Unsaturated Zone Parameters	Unsaturated Zone Thickness	√
	Unsaturated Zone Density	√
	Unsaturated Zone Total Porosity	√
	Unsaturated Zone Effective Porosity	√
	Unsaturated Zone Hydraulic Conductivity	√
	Unsaturated Zone b Parameter	√
Occupancy, Inhalation, And External Gamma Data	Inhalation rate	√
	Mass loading for inhalation	√
	Exposure duration	
	Indoor dust filtration factor	√
	External gamma shielding factor	√
	Indoor time fraction	
	Outdoor time fraction	
Ingestion Pathway, Dietary Data	Soil ingestion	√
	Drinking water intake	√
	Contaminated fraction Drinking water	
	Depth of soil mixing layer	√
	Groundwater Fractional Usage Drinking Water	
Storage Times Before Use Data	Well water	
	Surface water	

Table 2

Parameters of Industrial worker Scenario Available for Sensitivity Analysis but not Evaluated

Transport Solubility Limit:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Transport Leach Rate:	This parameter was not used by RESRAD since a distribution coefficient was provided.
Area of contaminated zone:	The NRC has previously examined this parameter input and found change does not significantly influence the DCGLs. ^a
Cover depth:	The dose assessment included the conservative assumption that no cover will be applied.
Irrigation:	Not applicable for industrial worker scenario.
Watershed area ...	The dose assessment included the actual value for this parameter.
Accuracy ... computations:	A sufficient value for accuracy was chosen.
Water table drop rate:	The dose assessment included the actual condition that the groundwater system is unconfined.
Well pumping rate:	See well pump intake depth (previous).
Exposure duration:	This parameter is not applicable since the model result is evaluated as peak dose and not total dose or risk.
Indoor time fraction:	By implication of NRC review of the parameter input for outdoor time fraction (see next), the input is reasonable for an industrial land-use scenario.
Outdoor time fraction:	The NRC has previously examined this parameter input and found the input reasonable for an industrial land-use scenario. ^a
Contaminated fraction Drinking water:	The dose assessment in this case represents the bounding assumption that contaminated drinking water is used on site.
Groundwater fractional Usage Drinking Water:	The dose assessment in this case represents the bounding assumption that contaminated drinking water is used on site.
Storage Times Before Use:	These parameters are not applicable since the scenario does not include any water storage.

^a U.S. Nuclear Regulatory Commission. SAFETY EVALUATION REPORT FOR LICENSE AMENDMENT APPLICATION TO APPROVE DECOMMISSIONING DATED JULY 24, 2003. Fansteel, Inc., Docket 040-7580, October 31, 2003.

Table 3

**PARAMETERS OF INDUSTRIAL WORKER SCENARIO NOT AVAILABLE FOR
SENSITIVITY ANALYSIS**

PARAMETER CATEGORY	PARAMETER DESCRIPTION
Source	Basic Radiation Dose Limit
	Transport Time since material placement
	Transport Groundwater concentration
Calculation Parameters	Times for Calculation
Cover and Contaminated Zone Hydrological Data	Density of cover material
	Cover erosion rate
	Humidity in air
	Irrigation mode
Saturated Zone Hydrological Data	Saturated zone b parameter
	Model for Water Transport Parameters
Occupancy, Inhalation, And External Gamma Data	Shape of the contaminated zone
Ingestion Pathway, Dietary Data	{All} consumption
	Contaminated fractions {All, except Drinking water}
Ingestion Pathway, Nondietary Data	Livestock ... intake for {All}
	Mass loading for foliar deposition
	Depth of roots
	Groundwater Fractional Usage {All, except Drinking water}
	Plant Factors {All}
Radon	{ All }

Table 4
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VALUE AND BASIS OF MULTIPLIER FOR SENSITIVITY ANALYSIS RANGE

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER		
	25 TH PERCENTILE ¹	MODEL	75 TH PERCENTILE ¹
Transport Distribution coefficient, ml/g			
uranium	15	126	1046
protactinium	43	380	3339
actinium	94	825	7284
thorium	511	5884	67745
radium	1122	3533	11131
lead	371	2392	15414
Density of contaminated zone, g/cm ³	1.52	1.67	1.82
Contaminated zone total porosity, dimensionless	0.31	0.37	0.43
Contaminated zone hydraulic conductivity, m/y	0.18	0.94	4.77
Contaminated zone b parameter, dimensionless	6.44	8.25	10.57
Density of saturated zone, g/m ³	1.40	1.51	1.62
Saturated zone total porosity, dimensionless	0.39	0.43	0.47
Saturated zone effective porosity, dimensionless	0.34	0.38	0.42
Saturated zone hydraulic conductivity, m/y	1457	2506	3659
Saturated zone hydraulic gradient, dimensionless	0.01	0.027	0.073
Density of unsaturated Zone 1, g/m ³	1.52	1.67	1.82
Unsaturated Zone 1 total porosity, dimensionless	0.31	0.37	0.43
Unsaturated Zone 1 effective porosity, dimensionless	0.22	0.29	0.35
Unsaturated Zone 1 hydraulic conductivity, m/y	0.18	0.94	4.77
Unsaturated Zone 1 b parameter, dimensionless	6.44	8.25	10.57
	MINIMUM ²	MODEL	MAXIMUM ²
Well pump intake depth (m below water table)	4.3	6.5	9.8
Thickness of contaminated zone, m	0.5	0.85	3
Uncontaminated Unsaturated Zone 1, Thickness, m	1.8	2.75	4.1

¹ U.S. Nuclear Regulatory Commission. Consolidated Decommissioning Guidance, Characterization, Survey, and Determination of Radiological Criteria, Final Report. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG-1757. September 2006. {Vol. 2, Rev. 1, App. I, Section I.6.4.4}

² Site specific estimates from Fansteel. "Decommissioning Plan, Fansteel, Muskogee, Oklahoma Site", Rev. 0. January 14, 2003. [ML030240051] {Section 3.5.2 and Table 5-4}

Table 4
(2 of 2)

VALUE AND BASIS OF MULTIPLIER FOR SENSITIVITY ANALYSIS RANGE

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER	
	MODEL	MULTIPLIER
Length parallel to aquifer flow, m	239	10
Basis for value of multiplier	Arbitrary as an order of magnitude.	
Contaminated zone erosion rate, m/y	0.0006	10
Basis for value of multiplier	Arbitrary as an order of magnitude.	
Contaminated zone field capacity, dimensionless	0.38	1.5
Basis for value of multiplier	An expected variation.	
Evapotranspiration coefficient, dimensionless	0.645	1.16
Basis for value of multiplier	A maximum expected variation. ¹	
Wind Speed, m/s	3.2	1.5
Basis for value of multiplier	A maximum expected variation.	
Precipitation, m/y	1.19	1.5
Basis for value of multiplier	A maximum expected variation.	
Runoff coefficient, dimensionless	0.4	1.5
Basis for value of multiplier	A maximum expected variation. ²	
Saturated zone field capacity, dimensionless	0.1	1.5
Basis for value of multiplier	An expected variation.	
Uncontaminated Unsaturated zone field capacity	0.38	1.5
Basis for value of multiplier	An expected variation.	
Inhalation rate, m ³ /y	8400	1.36
Basis for value of multiplier	An expected variation.	
Mass loading for inhalation, g/m ³	0.00023	1.5
Basis for value of multiplier	An expected variation. ²	
Indoor dust filtration factor, dimensionless	0.58	1.7
Basis for value of multiplier	A maximum expected variation. ²	
External gamma shielding factor, dimensionless	0.27	1.5
Basis for value of multiplier	An expected variation. ²	
Soil ingestion, g/y	18.3	2
Basis for value of multiplier	A maximum expected variation. ²	
Drinking water intake, L/y	250	2
Basis for value of multiplier	A maximum expected variation.	
Depth of soil mixing layer, m	0.15	4
Basis for value of multiplier	A maximum expected variation. ²	

² U.S. Nuclear Regulatory Commission. Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes. Washington, D.C.: U.S. Nuclear Regulatory Commission. NUREG/CR-6697. December 2000.

TABLE 5
SOURCE TERM FOR SENSITIVITY ANALYSES

Radionuclide	Original DCGL pCi/g	Original DCGL₁ limited to Unat by U-238 pCi/g	Sensitivity Analyses DCGL as ratio DCGL₁/DCGL_{Th-232} pCi/g
U-238 + D	1058	1058	77
U-234	2880	1058	77
U-235 + D	285	48	3
Pa-231	34.2	---	2
Ac-227 + D	39.0	---	3
Th-232	13.8	---	1
Th-230	59.0	---	4
Th-228 + D	27.5	---	2
Ra-226 + D	21.2	---	2
Ra-228 + D	24.5	---	2
Pb-210 + D	780	---	57

Table 6
(1 of 2)

SUMMARY OF SENSITIVITY ANALYSIS FOR INDUSTRIAL WORKER SCENARIO

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER		
	LOW	MODEL	HIGH
Transport Distribution coefficient: ml/g uranium	15	126	1046
Maximum Dose, mrem/y	153	13	13
protactinium	43	380	3339
Maximum Dose, mrem/y	30	13	13
actinium	94	825	7284
Maximum Dose, mrem/y	13	13	13
thorium	511	5884	67745
Maximum Dose, mrem/y	13	13	13
radium	1122	3533	11131
Maximum Dose, mrem/y	13	13	13
lead	371	2392	15414
Maximum Dose, mrem/y	13	13	13
Thickness of contaminated zone, m	0.5	0.85	3
Maximum Dose, mrem/y	13	13	13
Density of contaminated zone, g/cm ³	1.52	1.67	1.82
Maximum Dose, mrem/y	13	13	13
Contaminated zone erosion rate, m/y	0.000006	0.00006	0.0006
Maximum Dose, mrem/y	13	13	13
Contaminated zone total porosity, dimensionless	0.31	0.37	0.43
Maximum Dose, mrem/y	13	13	13
Contaminated zone field capacity, dimensionless	0.25	0.38	0.57
Maximum Dose, mrem/y	13	13	13
Contaminated zone hydraulic conductivity, m/y	0.18	0.94	4.77
Maximum Dose, mrem/y	13	13	13
Contaminated zone b parameter, dimensionless	6.44	8.25	10.57
Maximum Dose, mrem/y	13	13	13
Density of saturated zone, g/m ³	1.40	1.51	1.62
Maximum Dose, mrem/y	13	13	13
Saturated zone total porosity, dimensionless	0.39	0.43	0.47
Maximum Dose, mrem/y	13	13	13
Saturated zone effective porosity, dimensionless	0.34	0.38	0.42
Maximum Dose, mrem/y	13	13	13
Saturated zone field capacity, dimensionless	0.07	0.1	0.15
Maximum Dose, mrem/y	13	13	13
Saturated zone hydraulic conductivity, m/y	1457	2506	3659
Maximum Dose, mrem/y	13	13	13
Saturated zone hydraulic gradient, dimensionless	0.01	0.027	0.073
Maximum Dose, mrem/y	13	13	13

Table 6
(2 of 2)

SUMMARY OF SENSITIVITY ANALYSIS FOR INDUSTRIAL WORKER SCENARIO

DOSE ASSESSMENT PARAMETER	VALUE OF PARAMETER		
	LOW	MODEL	HIGH
Uncontaminated Unsaturated Zone 1, Thickness, m	1.8	2.75	4.1
Maximum Dose, mrem/y	13	13	13
Density of Unsaturated Zone 1, g/m ³	1.52	1.67	1.82
Maximum Dose, mrem/y	13	13	13
Unsaturated Zone 1 total porosity, dimensionless	0.31	0.37	0.43
Maximum Dose, mrem/y	13	13	13
Unsaturated Zone 1 effective porosity, dimensionless	0.22	0.29	0.35
Maximum Dose, mrem/y	13	13	13
Unsaturated Zone 1 field capacity, dimensionless	0.25	0.38	0.57
Maximum Dose, mrem/y	13	13	13
Unsaturated Zone 1 hydraulic conductivity, m/y	0.18	0.94	4.77
Maximum Dose, mrem/y	13	13	13
Unsaturated Zone 1 hydraulic gradient, dimensionless	6.44	8.25	10.57
Maximum Dose, mrem/y	13	13	13
Well pump intake depth	4.3	6.5	9.8
Maximum Dose, mrem/y	13	13	13
Length parallel to aquifer flow, m	24	239	2400
Maximum Dose, mrem/y	13	13	13
Evapotranspiration coefficient, dimensionless	0.56	0.645	0.75
Maximum Dose, mrem/y	13	13	13
Wind Speed, m/s	2.1	3.2	4.8
Maximum Dose, mrem/y	13	13	11
Precipitation, m/y	0.79	1.19	1.79
Maximum Dose, mrem/y	13	13	13
Runoff coefficient, dimensionless	0.27	0.4	0.6
Maximum Dose, mrem/y	13	13	13
Inhalation rate, m ³ /y	6180	8400	11400
Maximum Dose, mrem/y	12	13	14
Mass loading for inhalation, g/m ³	0.00015	0.00023	0.0035
Maximum Dose, mrem/y	12	13	14
Indoor dust filtration factor, dimensionless	0.34	0.58	0.99
Maximum Dose, mrem/y	12	13	14
External gamma shielding factor, dimensionless	0.18	0.27	0.41
Maximum Dose, mrem/y	12	13	14
Soil ingestion, g/y	9.15	18.3	36.6
Maximum Dose, mrem/y	11	13	15
Drinking water intake, L/y	125	250	500
Maximum Dose, mrem/y	13	13	13
Depth of soil mixing layer, m	0.04	0.15	0.6
Maximum Dose, mrem/y	13	13	13